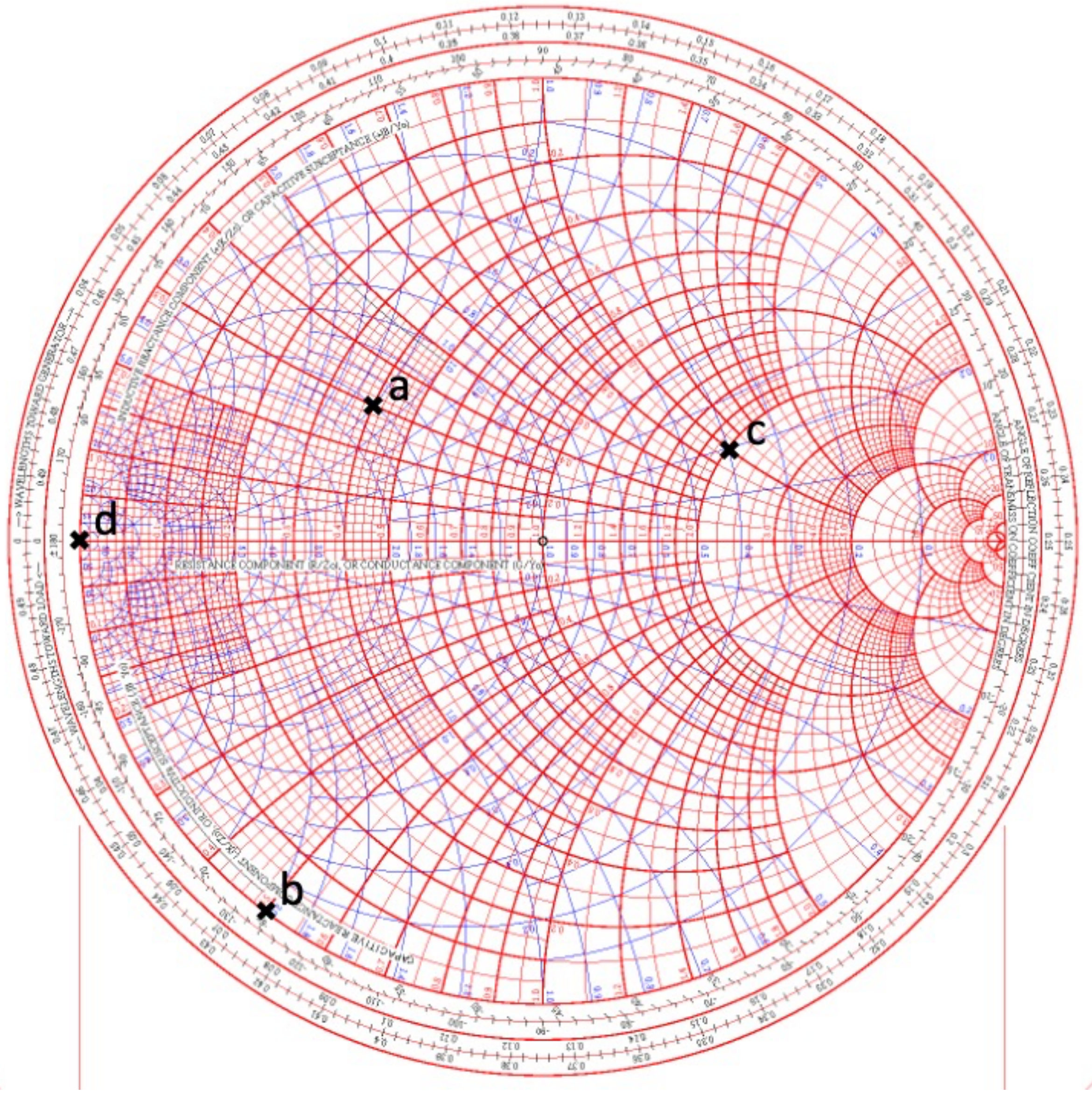
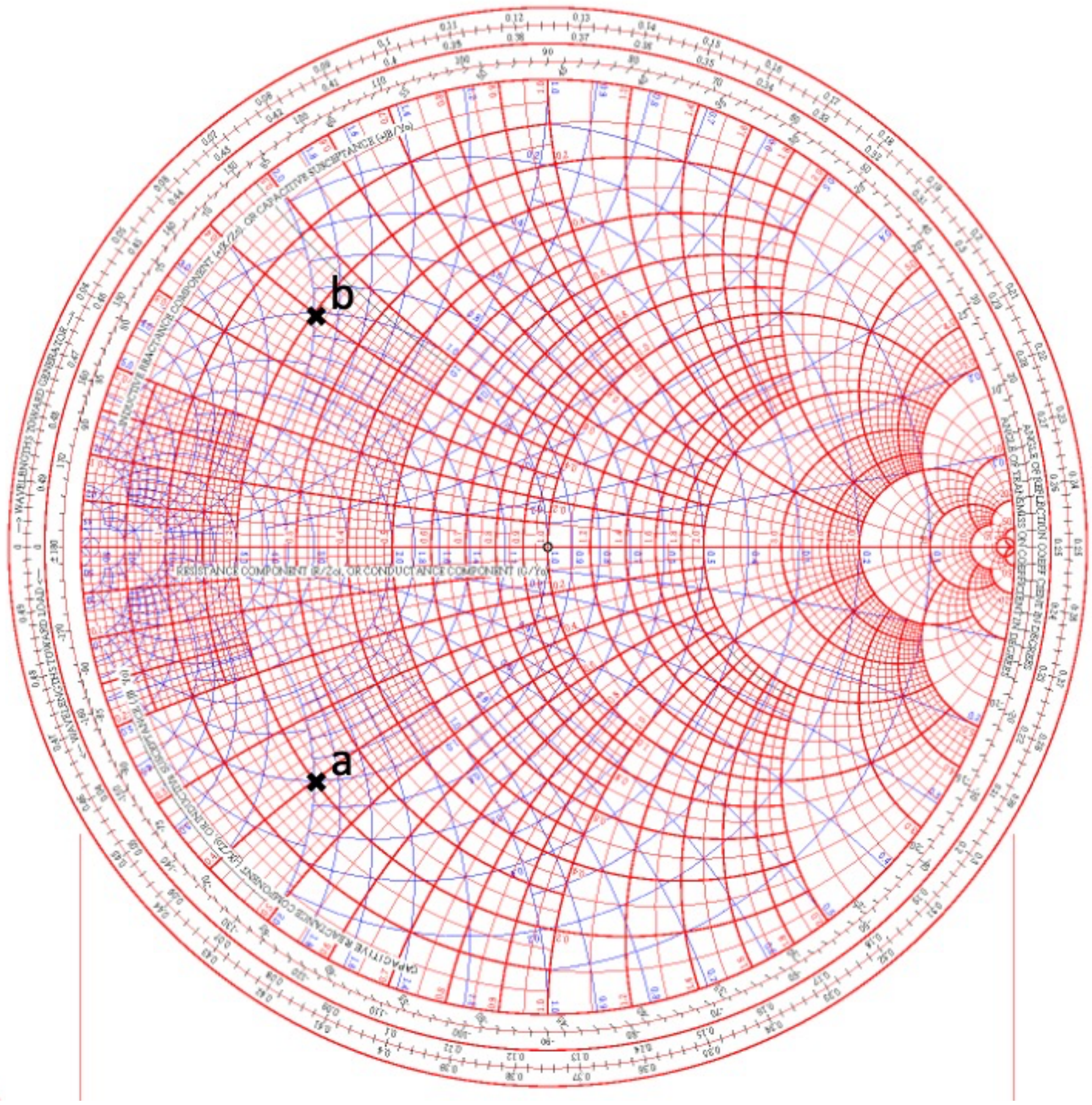
__Problem 1 (from old intermediate test)__



Problem 2 (a-d from old intermediate test)



(a) $Z_L' = 0.2 - j0.4$ – see Smith. Normalize first: $Z_L' = \frac{10-j20}{50} = 0.2 - j0.4$.

(b) You should rotate in the Smith chart to get to the point marked b.

(c) Read the normalized value from the smith chart using (b), and un-normalize it: $Z_{in}' = 0.2 + j0.4 \rightarrow Z_{in} = 50 \cdot Z_{in}' = 10 + j20$.

(d) Your answer should mention that you will use a capacitor in shunt (only), and that the value needed for it can be found by turning over the admittance.

Problem 3: Transmission lines and microwave networks (old exam question)

5XTCO – June 2020

Q1

a) $Z_L = (15 + j39)\,\Omega$

$Z_1 = 150\,\Omega$

$$\frac{Z_L}{Z_1} = \frac{15}{150} + j\frac{39}{150} = 0.1 + j\,0.26 \longrightarrow \text{find in SC}$$

$$|\Gamma_L| = 0.83$$

$$\measuredangle = 151^\circ$$

b)

$l_1 = 0.321\,m$, $\lambda = \frac{c}{f} = \frac{3\cdot 10^8\,m/s}{400\cdot 10^6\,1/s} = 0.75\,m$

$\frac{l_1}{\lambda} = 0.428 \iff l_1 = 0.428\lambda \longrightarrow$ Turn 0.428λ towards generator

$\frac{Z_L'}{Z_1} = 0.1 - j0.2 \longleftarrow$ in SC

$$Z_L' = (15 - j30)\,\Omega$$

c)

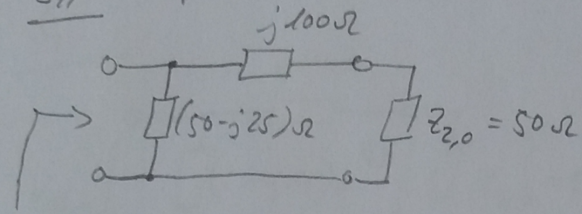
$$\frac{Z_L'}{Z_0} = \frac{15}{75} - j\frac{30}{75} = 0.2 - j\,0.4 \longrightarrow \text{find in SC}$$

From SC: $\frac{Y_L'}{Y_0} = 1 + j2 \Longrightarrow$ $Z_S = 0\,\Omega$

$Y_P = (-j2)\,Y_0 = -j\frac{2}{75}\frac{1}{\Omega}$

$$Z_P = j\,37.5\,\Omega$$

d) $\underline{S_{11}}$: Ref. impedance $\underline{Z_0 = 50\,\Omega}$



$\Gamma_1 = S_{11}$

$$Z_{in,1} = \underbrace{(50 - j25)\,\Omega}_{\text{find in SC}} \,\|\, \underbrace{(50 + j100)\,\Omega}_{\text{find in SC}} \rightarrow \frac{Z_2}{Z_0} = \frac{50}{50} + j\frac{100}{50} = \underbrace{1 + j2}_{\text{from SC}}$$

$$\frac{Z_1}{Z_0} = \frac{50}{50} - j\frac{25}{50}$$

$$\underbrace{\frac{Z_1}{Z_0} = 1 - j0.5}_{\text{from SC}}$$

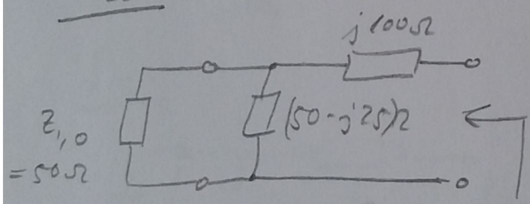
$$\frac{Y_2}{Y_0} = 0.2 - j0.4$$

$$\frac{Y_1}{Y_0} = 0.8 + j0.4 \rightarrow \boxed{\frac{Y_1 + Y_2}{Y_0} = 1} \text{ center of SC!}$$

$$\Rightarrow Z_{in,1} = 50\,\Omega$$

$$\Rightarrow \underline{\underline{S_{11} = 0}}$$

$\underline{S_{22}}$:



$\Gamma_2 = S_{22}$

$$Z_{in,2} = j100\,\Omega + \{\underbrace{50\,\Omega \,\|\, (50 - j25)\,\Omega}\}$$

$$\frac{Y_1}{Y_0} = 1 + 0.8 + j0.4$$

$$\frac{Y_1}{Y_0} = 1.8 + j0.4$$

$$\frac{Z_1}{Z_0} = 0.53 - j0.12$$

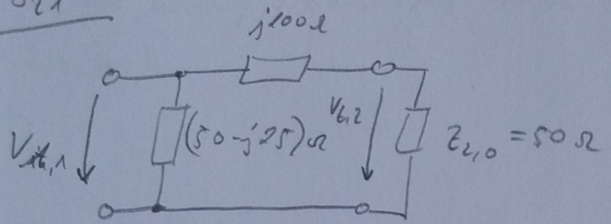
$$\cancel{j100\,\Omega} + Z_1 = 26.5 - j6$$

$$Z_{in,2} = (26.5 - j94)\,\Omega$$

$$\underline{\underline{S_{22}}} = \frac{Z_{in,2} - Z_0}{Z_{in,2} + Z_0} = \underline{\underline{0.48 + j0.64}}$$

d) cont'd

$\underline{S_{21}:}$



$V_{t,1} = (1+S_{11})\,V_{in,1}$; $\underline{V_{in,1}}$: incident voltage wave on port 1 (from the left)

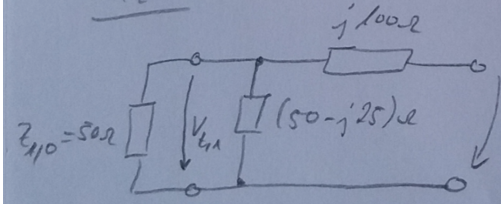
$$V_{t,2} = \frac{Z_{2,0}}{Z_{2,0}+j100\Omega}\,V_{t,1} = \frac{Z_{2,0}}{Z_{2,0}+j100\Omega}\,(1+S_{11})\,V_{in,1}$$; $\underline{V_{t,2}}$: accepted/dissipated power in $Z_{2,0}$ (i.e. port 2)

$$= \frac{50\Omega}{(50+j100)\Omega}\,(1+0)\,V_{in,1}$$

$$= \frac{1}{1+j2}\,V_{in,1} = \frac{1-j2}{5}\,V_{in,1} = (0.2-j0.4)\,V_{in,1}$$

$$\underline{\underline{S_{21}}} = \underbrace{\frac{V_{t,2}}{\sqrt{Z_0}}}_{b_2}\cdot\underbrace{\frac{\sqrt{Z_0}}{V_{in,1}}}_{\frac{1}{a_1}} = \frac{V_{t,2}}{V_{in,1}} = \underline{\underline{0.2-j0.4}}$$

$\underline{S_{12}:}$



$V_{t,2} = (1+S_{22})\,\underbrace{V_{in,2}}$ incident voltage wave on port 2 (from the right)

$V_{t,1}$: accepted/dissipated power in $Z_{1,0}$ (i.e. port 1)

$$V_{t,1} = \frac{\overbrace{50\Omega\,||\,(50-j25)\Omega}^{=Z_1}}{j100+\underbrace{\{50\Omega\,||\,(50-j25)\Omega\}}_{=Z_1=26.5-j6}}\,(1+\underbrace{S_{22}}_{=0.48+j0.64})\,V_{in,2}$$

$$\underline{\underline{S_{12}}} = \frac{V_{t,1}}{V_{in,2}} = \underline{\underline{0.2-j0.4}} = S_{21}$$ $\xrightarrow{!}$ This result could have been known without calculations. The network is passive and must be reciprocal $\Rightarrow$ S-matrix must be symmetrical!

e) The scattering matrix of the setup shown in Fig. 2 is not unitary, because the network contains lossy components (resistors).